Technical Report No. 89-01

Assessment of the Verme Weather Severity Index as Applied in Manitoba.

By Soprovich, Daniel W. and Hank Hristienko. 1989.

Manitoba
Natural Resources
Wildlife

89-04776/

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Technical Report No. 89-01, 50 pp.

ABSTRACT

Environmental measures necessary to calculation of the Verme Weather Severity Index have been collected in Manitoba since 1977. Assessment was made of the value of these measures as indicators of winter severity for several species of ungulates. There was no linear relationship between cumulative chillometer and cumulative minimum daily temperature for 3 of the 9 weather severity monitoring stations. Strong relationships were apparent for only 3 of the 9 weather severity monitoring stations. The period of collection of chillometer data was variable between years and stations. The snow cover does not provide support to the pentrometer until a crust forms, generally in the spring. Strong linear relationships between cumulative pentrometer and cumulative snow depth were apparent for 8 of the 9 weather severity monitoring stations, a function of the environmental conditions specific to Manitoba. A small sample size was likely the reason that a strong relationship was not found for 1 station. A lack of standardization of data collection and specific problems of data collection were apparent. The pentrometer overestimates the support provided to ungulates by a crust and fails to recognize the ability of crust to exclude food, allow predators to travel easily where ungulates cannot, and the relative unimportance of crust when ungulates feed upon agricultural residues and products. The chillometer fails to recognize the importance of thermal radiation on the ability of ungulates to remain within their thermal neutral zone. The problems identified with the pentrometer and chillometer as indicators of environmental stress for ungulates in Manitoba suggests that use of these instruments should cease. Metrification has a serious impact on the Verme Weather Severity Index. Index formation is of limited value and should not be used in isolation.

Submitted: July 1986
Distributed: March 1989

ACKNOWLEDGEMENTS

Vince Crichton recognized the utility of collecting measures important to the survival and reproduction of ungulates and initiated collection of those measures necessary for a Verme WSI. We thank all staff from the Department of Natural Resources who exercised care in the collection of snow depth, pentrometer, and chillometer data. We particularly thank staff from the districts of Falcon Lake, Hodgson, Lundar, Marchand, Piney, and Riverton who provided an opportunity to examine the collection of data in the field. Thanks to Merlin Shoesmith who reviewed several drafts of this report and to Cindy Little, Brenda Gluting and Lorraine Hosfield who collaborated to produce draft and final copies with a word processor.

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INTRODUCTION

Winter can be a period of extreme stress for ungulates in Manitoba. A number of measures and indices of weather severity have been utilized to assess the impact of winter. Snow depth and crust condition measures were collected in Manitoba beginning in the 1960's. These measures were used in the calculation of a weather severity index developed in Ontario (Milliken 1977). Calculation of the Ontario Index was discontinued in southwestern Manitoba following the 1975/76 winter. It was believed that the Ontario Index did not accurately portray the effect of Manitoba winters on white-tailed deer (Odocoileus virginianus) and that predicted mortality levels were not accurate as a consequence (Milliken 1977). The Ontario Index was last utilized in the Western Region of Manitoba during the 1976/77 winter (Minton 1977).

The measures necessary to calculation of the Verme Weather Severity Index (Verme 1968) or Verme WSI were first collected in the Interlake Region and the Eastern Region of Manitoba during the winter of 1977/78. These measures were collected in other areas of Manitoba during subsequent years. The Verme WSI is comprised of three separate measures collected on a weekly basis. The first component of the Verme WSI is a measure of snow depth. The second measure results from an instrument known as a compaction gauge or pentrometer. The purpose of this instrument is to assess the support which is provided a white-tailed deer by the snowpack. The third component results from a chillometer which is designed to assess thermal stress. The Verme WSI results when the three components are added together, and was believed to provide an accurate measure of the impact of winter weather on white-tailed deer in Michigan (Verme 1968). Verme (1977) subsequently found the proportion of white-tailed deer females in good physical condition and predicted natal birth weight to relate to the Verme WSI. As fetal birth weight and mortality are strongly related (Verme 1962, 1963), this suggests that natal mortality and subsequent recruitment would relate to the Verme WSI. Karns (1980) found an index of overwinter mortality to relate to the Verme WSI for white-tailed deer in Minnesota.

The data necessary to calculation of the Verme WSI were collected at various locations in Manitoba. The purpose of this study was to assess the quality of this data and the usefulness of the measures. The data assessed in this study came from weather severity monitoring stations located outside of southwestern Manitoba (Figure 1). The measures necessary to calculation of the Verme WSI were not collected in southwestern Manitoba until the 1979/80 winter. Analysis of that and other data from southwestern Manitoba is provided in a subsequent report.

METHODS

Weather Severity Monitoring Stations

Materials and methods as described by Verme (1968) were incorporated in establishing weather severity monitoring stations. Snow-related measurements were collected along a snow transect for each severity monitoring station. The snow transect consisted of 10 permanent stations with each station located 1 chain (20 m) from adjacent stations. The following criteria were used to assist the selection of locations for snow transects:

(i) the transect was to be located in a pure or nearly pure hardwood stand of moderate to heavy density with the average tree height being 6 m or greater;

(ii) the terrain was to be relatively level with little or no overall gradient in any direction (minor undulations of topography were allowed); and

(iii) the transect was not to pass within 40 m of any clearing, lake, road, or other opening which could lead to drifting snow.

The above criteria have been used to establish snow transects whose purpose was to determine the relationships between snow parameters and white-tailed deer (Verme 1968). A number of snow transects located in Manitoba were established to monitor snow characteristics as related to elk (Cervus elaphus) and moose (Alces alces). In an effort to recognize the

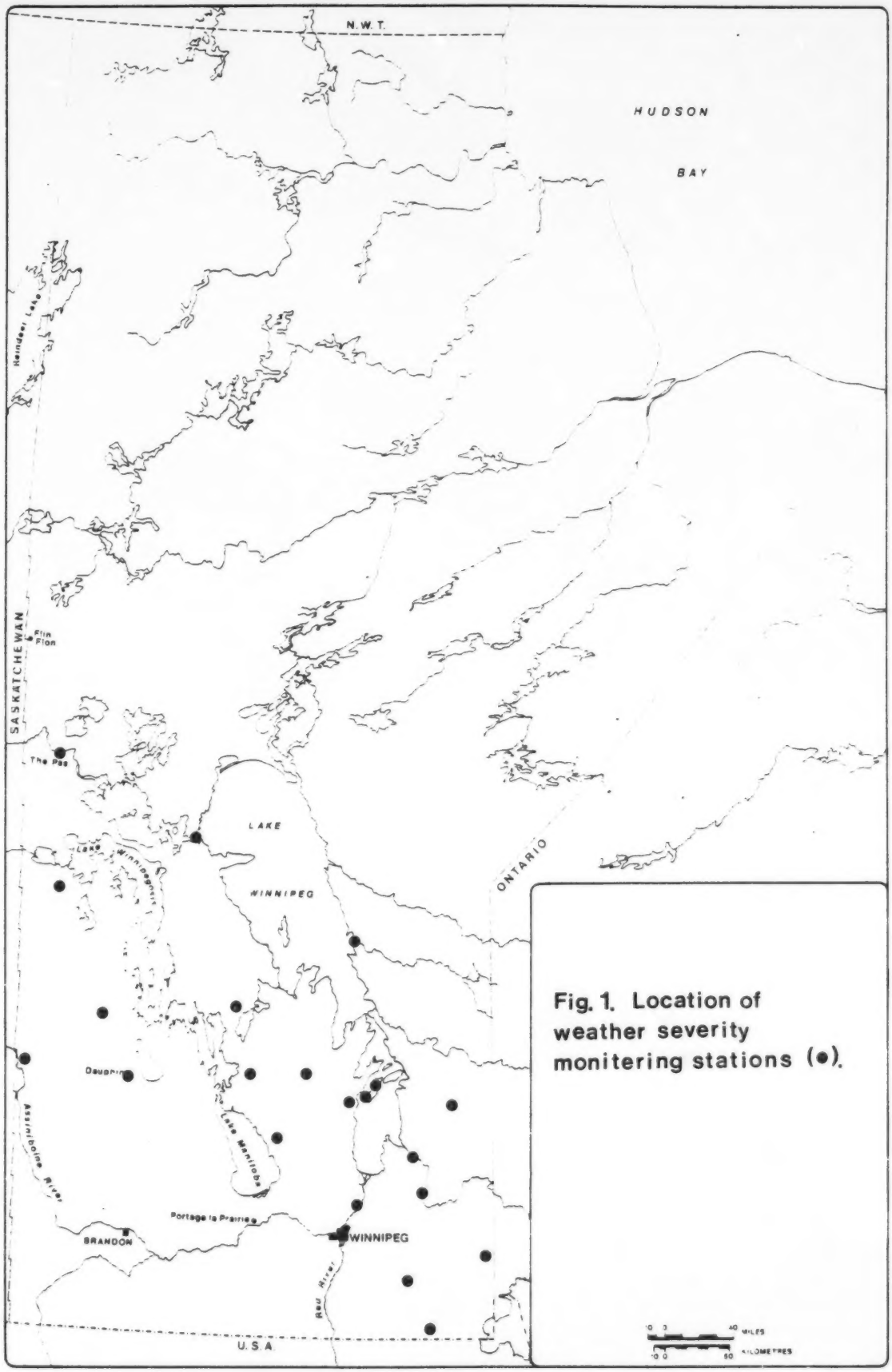

Fig. 1. Location of weather severity monitering stations (•).

biological differences between white-tailed deer and the other two species, some of the Manitoba snow transects did not meet criterion one (e.g., Hecla South).

Chillometers were located at only a portion of the weather severity monitoring stations. Verme WSI values for monitoring stations without chillometers were calculated by utilizing measurements from the nearest monitoring station with a chillometer.

Data were to be collected and recorded on WSI Report Cards (Appendix I) every Monday from 01 November (or when the first snow had fallen) to 01 May (or when all the snow had disappeared). The Report Cards were to be forwarded to the Wildlife Branch in Winnipeg for compilation. The following measurements were to be collected:

(i) Chillometer - The chillometer is a pressure cooker filled with distilled water which is maintained at 4 C with an electric heating element and a thermoregulator. An electricity meter records the amount of energy (in kW•hours) required to maintain the water at 4 C. The number of kW•hours used from one Monday to the next represents the chillometer value for any given week;

(ii) Crust - A subjective assessment of crust conditions along the snow transect was recorded. The categories included no crust, light crust and crust strong enough to support a man on snowshoes;

(iii) Pentrometer - The pentrometer is a sealed copper pipe filled with sand, weighing 1.36 kg (3 pounds) and having a base of 6.45 cm^2 (1 $inch^2$). The pentrometer is lowered to the surface of the snow and then released, exerting a force of approximately 211 g/cm^2 (approximately 3 $pounds/inch^2$) on the surface of the snow. Once the pentrometer has come to rest in the snow, it is grasped at snow level and removed. The depth (thickness) penetrated by the pentrometer was measured in cm. Pentrometer measurements were to be taken at each station along the snow transect;

(iv) Snow depth (thickness) - The snow depth was measured in cm with the use of a meter stick fastened to the stake marking each permanent station; and

(v) Temperature - Temperature was measured in C and was to be taken between 0800 and 0830 hours upon arrival of staff at the office. The minimum (coldest), maximum (warmest) and average temperatures were to be recorded in the appropriate columns on the WSI Report Cards.

Appraisal of the Weather Severity Index Data Base

Some report cards were missing data and/or contained data which were estimated rather than having been collected. For example, the area provided on the report card for the pentrometer measurement often contained the words "same as snow" without any measurements. It was obvious that the data were not collected but were estimated under these circumstances. A problem with this method of "data non-collection" is that the accuracy of these estimates is unknown (hence the accuracy of the data base becomes questionable). A consequence of this lack of data collection is that "best guess" values had been initially used for missing and estimated data to enable calculation of a WSI [WSI = cumulative snow depth (cm) + cumulative pentrometer (cm) + cumulative chillometer (kW·hour)].

The data base was reviewed to estimate the proportion which had actually been collected (i.e., was not estimated or missing on the original report cards) and to arrive at the most accurate values possible for the purpose of data analysis. The original values were sometimes adjusted to arrive at values believed to be more accurate. The data base was reviewed for the winters of 1980/81 to 1984/85 inclusive. The criteria used to appraise the data and to subjectively improve the "best guess" values are outlined below for each of the WSI variables.

The proportion of snow depth data which had actually been collected was determined using the following information. The number of report cards received from snowfall to snowmelt and the number of report cards which should have been received over this period were used to estimate

the number of missing report cards. Those report cards which duplicated data from the previous week were believed to represent data which had not been collected. The number of stations for which data were missing was taken directly from the report cards.

The snow depth values were adjusted by interpolation if several measures in a series were missing or estimated. Snow depth values were sometimes missing or estimated for relatively long periods of time (e.g., 2 months). The snow depth values were adjusted by using average measurements from adjacent monitoring stations under such circumstances.

The proportion of pentrometer data which had actually been collected was determined by using the same type of information used for the appraisal of snow depth data. The pentrometer data were treated as estimated when the average pentrometer value was the only pentrometer data recorded and was the same as the average snow depth, the pentrometer values were exactly the same as the snow depth values, or the pentrometer data were recorded as "the same as snow depth". There were report cards where the morning temperature was low (e.g., -20 C) and the subjective measures of crust indicated a supportive crust yet the pentrometer data indicated that the pentrometer was not supported by the crust. Such pentrometer data were considered to have been measured during the afternoon (rather than the morning when the observations were required to be taken) and were treated as estimated data.

When pentrometer data were missing or estimated, pentrometer measurements were divided by snow depth measurements from adjacent monitoring stations. These proportions were averaged and this average was multiplied by snow depth measurements from the monitoring station with the missing or estimated pentrometer data. The resulting values were used as the adjusted pentrometer values thought to represent the most accurate values for the pentrometer measurement.

Chillometer data were to be collected commencing 01 November. The proportion of chillometer data which had actually been collected was determined by dividing the number of weeks for which data had been collected (not missing) by the number of weeks in the data collection period (01

November to snowmelt). The chillometer data were deemed complete if starting (at 01 November) and ending (at snowmelt) electricity meter values were available. The cumulative chillometer value (equals total electrical consumption) for the winter period could be calculated by subtracting the starting value from the ending value hence the measure of chillometer was accurate for the purpose of data analysis.

The "best guess" chillometer values (those used originally for missing values) were adjusted in the following ways. Average values from adjacent monitoring stations were sometimes used to adjust "best guess" chillometer values. Chillometer values were also adjusted by using a value that would be expected for the specific monitoring station given the temperatures recorded during the week for which the chillometer datum was missing.

The adjusted WSI value was calculated by the addition of the adjusted values for cumulative snow depth, cumulative pentrometer and cumulative chillometer. This value was felt to represent the best estimate of the Verme WSI for the purpose of data analysis.

Evaluation of the Weather Severity Index

Several weather severity monitoring stations were visited during late March and early April of 1985. These stations included Marchand, Piney, Falcon Lake, Riverton, Hecla North, Hecla South, and Hodgson. Monitoring sites were visited with the person or one of the persons who generally collected the readings. Observations were recorded to assess comparability of methodology between stations.

Evaluation of cumulative weather severity data was made for those monitoring stations which possessed chillometers. These included weather severity monitoring stations at Garland, Piney, Marchand, Gypsumville, Riverton, Lac du Bonnet, Lundar, Hodgson, Bissett, and The Pas.

Chillometer data were not collected at Marchand during several years of the study period. Chillometer measurements from Piney had been used to calculate the WSI for Marchand during these years. The Marchand data set with chillometer data from the two sources was utilized in this

evaluation. Chillometers were located at Selkirk and The Pas; however, data sets were not evaluated for these monitoring stations. The majority of data from Selkirk was either of poor quality or missing. The WSI measures could not be separated into chillometer, pentrometer and snow depth components for 3 of the 6 years of data from The Pas.

Temperature data were obtained from the Monthly Record series, published by the Atmospheric Environment Service, Environment Canada. The data for the meteorological station located closest to each weather severity monitoring station were utilized in the analysis. Mean minimum temperatures for each month from November of one year to April of the next year were obtained from the Monthly Record series. Mean minimum temperatures were multiplied by the number of days in the month and summed to yield a cumulative minimum daily temperature for the period 01 November to 30 April. This measure is essentially the same as would be obtained by adding daily minimum temperatures together for the period with any difference the result of rounding error. A mean daily minimum temperature for the period would result if the cumulative minimum daily temperature was divided by the number of days in the period. The period from 01 November to 30 April is approximately the same period for which chillometer data were calculated. Cumulative minimum daily temperature, chillometer, snow depth and pentrometer measurements were entered into a computer (Hewlett-Packard Model 9830A) and a correlation matrix generated for each weather severity monitoring station.

Meteorological stations were generally located close to weather severity monitoring stations; however, the closest meteorological station was relatively distant in several cases (Table 1).

Table 1. Location of meteorological stations used to provide temperature data for comparison with data from weather severity monitoring stations.

WEATHER SEVERITY MONITORING STATION	METEOROLOGICAL STATION
The Pas	The Pas Airport
Garland	Dauphin Airport
Piney	Sprague
Marchand	Steinbach
Gypsumville	Ashern
Riverton	Arborg[a]
Lac du Bonnet	Pinawa W.N.R.E.
Lundar	Lundar 4 S.W.
Hodgson	Hodgson 2
Bissett	Bissett

[a]Data from Gimli used for two missing values.

RESULTS

Appraisal of the Weather Severity Index Data Base

It was assessed that <50% of the value had actually been collected for 9% of the WSI values from the winters of 1980/81 to 1984/85 inclusive (Tables 2 to 6). Only 59% of the calculated values were assessed to have had >75% of their content actually collected.

Original "best guess" values were subjectively improved during the appraisal process and these figures are presented in Table 7 along with the percentages by which they were adjusted. The adjustment of original values varied from a decrease of 18.6% to an increase of 43.9%. In four instances, report card recordings were so scant that a WSI value could not be determined.

Table 2. Appraisal of weather severity index data for 1980/81.

WEATHER SEVERITY MONITORING STATION	% OF SNOW DEPTH ACTUALLY COLLECTED (ADJUSTED SNOW DEPTH)	% OF PENTROMETER ACTUALLY COLLECTED (ADJUSTED PENTROMETER)	% OF CHILLOMETER ACTUALLY COLLECTED (ADJUSTED CHILLOMETER)[a]	% OF WSI ACTUALLY COLLECTED (ADJUSTED WSI)
The Pas[b]	Un[c]	Un	Un	Un (1079)
Dauphin	Un	Un	Un	0 (Un)
Garland[b]	89 (203)	100 (126)	95 (105)	95 (434)
Mafeking	100 (203)	0 (175)	95 (102)	65 (480)
Roblin	85 (397)	85 (378)	95 (105)	88 (880)
Ashern	89 (261)	89 (201)	71 (130)	83 (592)
Grand Rapids	74 (422)	74 (301)	71 (135)	73 (858)
Gypsumville[b]	100 (463)	85 (356)	71 (135)	85 (954)
Hodgson[b]	87 (295)	0 (235)	79 (110)	55 (640)
Lundar[b]	83 (318)	0 (244)	71 (127)	51 (689)
Riverton[b]	100 (371)	100 (306)	100 (158)	100 (835)
Hecla N.	75 (469)	85 (366)	100 (158)	87 (993)
Hecla S.	75 (478)	85 (387)	100 (158)	87 (1023)
Bissett[b]	94 (356)	89 (274)	100 (111)	94 (741)
Lac du Bonnet[b]	100 (350)	100 (287)	100 (118)	100 (755)
L.W. East	70 (415)	0 (327)	100 (111)	57 (853)
Pine Falls	84 (300)	84 (281)	100 (121)	89 (702)
Falcon Lake	86 (238)	86 (180)	70 (125)	81 (543)
Marchand[b]	100 (187)	100 (170)	70 (125)	90 (482)
Piney[b]	100 (241)	57 (203)	70 (125)	76 (569)
Selkirk[b]	Inconsistent data collection, thus appraisal could not be made.			

[a]Chillometer data from adjacent monitoring station were used for those stations without chillometers.
[b]Station with a chillometer.
[c]Un=Unknown.

Table 3. Appraisal of weather severity index data for 1981/82.

WEATHER SEVERITY MONITORING STATION	% OF SNOW DEPTH ACTUALLY COLLECTED (ADJUSTED SNOW DEPTH)	% OF PENTROMETER ACTUALLY COLLECTED (ADJUSTED PENTROMETER)	% OF CHILLOMETER ACTUALLY COLLECTED (ADJUSTED CHILLOMETER)[a]	% OF WSI ACTUALLY COLLECTED (ADJUSTED WSI)
The Pas[b]	Un[c]	Un	Un	Un (1498)
Dauphin	54 (205)	0 (184)	95 (128)	50 (517)
Garland[b]	92 (186)	69 (167)	95 (128)	85 (481)
Mafeking	50 (233)	0 (209)	95 (128)	50 (570)
Roblin	87 (305)	0 (273)	87 (135)	58 (713)
Ashern	100 (271)	94 (237)	75 (161)	90 (669)
Grand Rapids	95 (736)	38 (676)	79 (175)	71 (1587)
Gypsumville[b]	100 (338)	83 (317)	79 (175)	87 (830)
Hodgson[b]	69 (301)	0 (261)	100 (151)	56 (713)
Lundar[b]	100 (320)	0 (277)	75 (161)	58 (758)
Riverton[b]	100 (346)	94 (280)	100 (151)	98 (777)
Hecla N.	100 (447)	67 (402)	100 (151)	89 (1000)
Hecla S.	100 (388)	67 (340)	100 (151)	89 (879)
Bissett[b]	100 (394)	6 (327)	91 (137)	66 (791)
Lac du Bonnet[b]	100 (448)	84 (359)	100 (140)	95 (947)
L.W. East	40 (368)	0 (321)	88 (140)	44 (829)
Pine Falls	29 (394)	0 (327)	100 (140)	43 (794)
Falcon Lake	85 (591)	95 (429)	55 (144)	78 (1164)
Marchand[b]	100 (484)	95 (443)	55 (148)	83 (1075)
Piney[b]	89 (486)	0 (375)	71 (131)	53 (992)
Selkirk[b]	Un	Un	Un	Un

[a]Chillometer data from adjacent monitoring station were used for those stations without chillometers.
[b]Station with a chillometer.
[c]Un=Unknown.

Table 4. Appraisal of weather severity index data for 1982/83.

WEATHER SEVERITY MONITORING STATION	% OF SNOW DEPTH ACTUALLY COLLECTED (ADJUSTED SNOW DEPTH)	% OF PENTROMETER ACTUALLY COLLECTED (ADJUSTED PENTROMETER)	% OF CHILLOMETER ACTUALLY COLLECTED (ADJUSTED CHILLOMETER)[a]	% OF WSI ACTUALLY COLLECTED (ADJUSTED WSI)
The Pas[b]	33 (838)	0 (576)	46 (170)	26 (1548)
Dauphin	82 (598)	82 (357)	100 (139)	88 (1094)
Garland[b]	100 (716)	100 (470)	100 (139)	100 (1325)
Mafeking	92 (951)	50 (697)	100 (139)	81 (1787)
Roblin	100 (642)	73 (488)	100 (139)	91 (1269)
Ashern	100 (331)	100 (231)	75 (148)	92 (710)
Grand Rapids	96 (893)	91 (726)	81 (154)	89 (1773)
Gypsumville[b]	100 (679)	58 (526)	84 (151)	81 (1356)
Hodgson[b]	89 (292)	0 (217)	100 (117)	63 (626)
Lundar[b]	85 (178)	0 (143)	75 (148)	53 (469)
Riverton[b]	100 (334)	75 (290)	100 (138)	92 (762)
Hecla N.	94 (352)	94 (286)	100 (138)	96 (776)
Hecla S.	94 (328)	94 (300)	100 (138)	96 (766)
Bissett[b]	80 (379)	0 (299)	82 (111)	54 (789)
Lac du Bonnet[b]	93 (237)	71 (174)	95 (119)	86 (530)
L.W. East	NA[c]	NA	NA	NA
Pine Falls	93 (326)	93 (203)	91 (121)	92 (650)
Falcon Lake	80 (335)	0 (262)	64 (122)	48 (719)
Marchand[b]	77 (197)	77 (158)	64 (122)	73 (477)
Piney[b]	89 (323)	56 (278)	64 (122)	70 (723)
Selkirk[b]	64 (271)	0 (197)	64 (122)	43 (590)

[a]Chillometer data from adjacent monitoring station were used for those stations without chillometers.
[b]Station with a chillometer.
[c]NA=Not available.

Table 5. Appraisal of weather severity index data for 1983/84.

WEATHER SEVERITY MONITORING STATION	% OF SNOW DEPTH ACTUALLY COLLECTED (ADJUSTED SNOW DEPTH)	% OF PENTROMETER ACTUALLY COLLECTED (ADJUSTED PENTROMETER)	% OF CHILLOMETER ACTUALLY COLLECTED (ADJUSTED CHILLOMETER)[a]	% OF WSI ACTUALLY COLLECTED (ADJUSTED WSI)
The Pas[b]	56 (478)	0 (412)	100 (180)	52 (1070)
Dauphin	59 (324)	59 (273)	90 (121)	69 (718)
Garland[b]	95 (354)	100 (310)	90 (121)	95 (785)
Mafeking	76 (520)	71 (350)	90 (121)	79 (991)
Roblin	100 (386)	47 (383)	90 (121)	79 (890)
Ashern	100 (416)	89 (368)	76 (147)	88 (931)
Grand Rapids	95 (652)	86 (543)	81 (163)	87 (1358)
Gypsumville[b]	85 (594)	0 (513)	81 (163)	55 (1270)
Hodgson[b]	89 (457)	0 (400)	90 (115)	60 (972)
Lundar[b]	74 (416)	0 (368)	76 (147)	50 (931)
Riverton[b]	94 (464)	56 (446)	95 (146)	82 (1056)
Hecla N.	100 (446)	53 (429)	95 (146)	83 (1021)
Hecla S.	100 (496)	53 (481)	95 (146)	83 (1123)
Bissett[b]	95 (590)	0 (512)	95 (117)	63 (1219)
Lac du Bonnet[b]	58 (477)	58 (341)	90 (129)	69 (947)
L.W. East	79 (621)	0 (539)	95 (117)	58 (1277)
Pine Falls	79 (478)	79 (370)	90 (129)	83 (977)
Falcon Lake	95 (599)	0 (534)	71 (78)	55 (1211)
Marchand[b]	100 (422)	95 (388)	71 (78)	89 (888)
Piney[b]	89 (460)	89 (278)	71 (78)	83 (816)
Selkirk[b]	68 (519)	0 (439)	57 (120)	42 (1078)

[a]Chillometer data from adjacent monitoring station were used for those stations without chillometers.
[b]Station with a chillometer.

Table 6. Appraisal of weather severity index data for 1984/85.

WEATHER SEVERITY MONITORING STATION	% OF SNOW DEPTH ACTUALLY COLLECTED (ADJUSTED SNOW DEPTH)	% OF PENTROMETER ACTUALLY COLLECTED (ADJUSTED PENTROMETER)	% OF CHILLOMETER ACTUALLY COLLECTED (ADJUSTED CHILLOMETER)[a]	% OF WSI ACTUALLY COLLECTED (ADJUSTED WSI)
The Pas[b]	58 (754)	8 (531)	96 (216)	54 (1501)
Dauphin	100 (1052)	64 (835)	91 (144)	85 (2031)
Garland[b]	95 (848)	100 (647)	91 (144)	95 (1639)
Mafeking	52 (973)	56 (620)	91 (144)	66 (1737)
Roblin	100 (1112)	100 (1081)	91 (144)	97 (2337)
Ashern	100 (607)	100 (442)	85 (205)	95 (1254)
Grand Rapids	91 (935)	58 (770)	100 (162)	83 (1867)
Gypsumville[b]	100 (778)	0 (551)	100 (162)	67 (1491)
Hodgson[b]	95 (705)	32 (554)	100 (140)	76 (1399)
Lundar[b]	91 (516)	0 (337)	85 (205)	55 (1058)
Riverton[b]	96 (733)	74 (456)	70 (142)	80 (1331)
Hecla N.	91 (642)	91 (534)	70 (142)	84 (1318)
Hecla S.	91 (673)	91 (589)	70 (142)	84 (1404)
Bissett[b]	86 (505)	0 (355)	95 (122)	60 (982)
Lac du Bonnet[b]	73 (558)	0 (373)	100 (145)	58 (1076)
L.W. East	76 (742)	0 (562)	95 (122)	57 (1426)
Pine Falls	77 (491)	77 (344)	95 (150)	83 (985)
Falcon Lake	100 (561)	91 (510)	81 (106)	91 (1177)
Marchand[b]	90 (430)	100 (416)	81 (104)	90 (950)
Piney[b]	76 (447)	76 (374)	76 (104)	76 (925)
Selkirk[b]	55 (419)	0 (351)	45 (101)	33 (871)

[a]Chillometer data from adjacent monitoring station were used for those stations without chillometers.
[b]Station with a chillometer.

Table 7. Adjusted weather severity index values and % adjusted (in brackets) for the years 1980/81 to 1984/85 inclusive.

WEATHER SEVERITY MONITORING STATION	1980/81	1981/82	1982/83	1983/84	1984/85
The Pas[a]	1079 (NE[b])	1498 (NE)	1584 (-6.1)	1070 (-6.5)	1501 (-9.4)
Dauphin	NE (NE)	517 (NE)	1094 (-0.4)	718 (-6.3)	2031 (0)
Garland[a]	434 (+3.5)	481(-18.6)	1325 (-2.2)	785 (-5.7)	1639 (0)
Mafeking	480 (-7.5)	570 (NE)	1787 (-1.1)	991 (-3.8)	1737 (-2.6)
Roblin	880 (+3.6)	713 (-4.0)	1269 (-0.3)	890 (-8.0)	2337 (0)
Ashern	592 (-6.9)	669 (-4.4)	710 (-5.7)	931 (+0.8)	1254 (-1.6)
Grand Rapids	858 (-5.0)	1587 (+4.4)	1773 (-2.5)	1358 (+1.0)	1867 (-1.9)
Gypsumville[a]	954 (+0.8)	830 (-2.6)	1356 (-5.6)	1270 (-4.9)	1491(-13.2)
Hodgson[a]	640(-12.5)	713 (+1.8)	626 (-7.9)	972 (-5.7)	1399 (-5.4)
Lundar[a]	689(-12.8)	758(+43.9)	469 (-9.5)	931 (-0.3)	1058 (-8.7)
Riverton[a]	835 (-1.0)	777 (-1.5)	762 (-9.1)	1056 (+1.1)	1331 (-2.2)
Hecla N.	993 (-1.1)	1000 (+5.4)	776 (-2.0)	1021 (-0.4)	1318 (-0.7)
Hecla S.	1023 (+0.8)	879 (+3.4)	766 (-2.1)	1123 (-0.4)	1404 (-1.5)
Bissett[a]	741 (-5.1)	791 (-9.0)	789 (-2.7)	1219 (-6.1)	982 (-4.2)
Lac du Bonnet[a]	755 (+0.8)	947 (+0.1)	530 (-6.5)	947 (-5.5)	1076 (+2.8)
L.W. East	853 (-3.0)	829 (+5.9)	NE (NE)	1277 (-7.7)	1426 (NE)
Pine Falls	702 (+1.1)	794(-12.5)	650(-11.9)	977 (-3.6)	985 (+0.5)
Falcon Lake	543 (+2.0)	1164 (-8.8)	719(-12.2)	1211 (-5.6)	1177 (0)
Marchand[a]	482 (-2.8)	1075 (-1.8)	477(-10.5)	888 (-1.0)	950 (+2.5)
Piney[a]	569 (+7.4)	992 (NE)	723 (-3.7)	816(-13.0)	925 (+0.1)
Selkirk[a]	NE (NE)	NE (NE)	590(-15.7)	1078 (-7.4)	871 (NE)

[a]Station with a chillometer
[b]NE=No evaluation made due to insufficient data.

Chillometer

Appendix II details chillometer and cumulative minimum daily temperature values for each weather severity monitoring station. Chillometer values did not relate well to cumulative minimum daily temperature values in a number of instances (Table 8). The chillometer value from The Pas for 1983/84 is higher than that for 1982/83 despite the winter having been considerably warmer. Similar comparisons are apparent for the other weather severity monitoring stations.

Cumulative daily minimum temperatures were lower at Hodgson than Lundar during all 8 years examined (Table 9). The chillometer value was higher at Lundar for 7 of the 8 years. The mean cumulative daily minimum temperature was lower at Hodgson yet the mean chillometer value was 22% higher at Lundar. The cumulative minimum daily temperature was -2916 C for Lundar and -3273 C for Hodgson for the winter of 1984/85 yet the chillometer value for Lundar (205) was considerably higher than that for Hodgson (140).

Table 8. Chillometer and cumulative minimum daily temperature values for several weather severity monitoring stations.

WEATHER SEVERITY MONITORING STATION	YEAR	CHILLOMETER (kW•hours)	CUMULATIVE MINIMUM DAILY TEMPERATURE (C)
The Pas	1982/83	170	-3053
	1983/84	180	-2566
Gypsumville	1978/79	181	-3766
	1979/80	182	-2926
Riverton	1978/79	195	-3626
	1979/80	193	-2955
	1980/81	158	-2448
	1981/82	151	-3012
Lac du Bonnet	1981/82	140	-2718
	1984/85	145	-2579
Lundar	1977/78	192	-3154
	1978/79	168	-3746
	1981/82	161	-3180
	1984/85	205	-2916
Hodgson	1977/78	138	-3403
	1979/80	149	-3293
Bissett	1977/78	161	-3360
	1978/79	153	-3614

Table 9. Comparison of cumulative minimum daily temperature and chillometer data for Lundar and Hodgson.

YEAR	CUMULATIVE MINIMUM DAILY TEMPERATURE (C)		CHILLOMETER (kW•hours)	
	Lundar	Hodgson	Lundar	Hodgson
1977/78	-3154	-3403	192	138
1978/79	-3746	-3868	168	171
1979/80	-2959	-3293	181	149
1980/81	-2487	-2717	127	110
1981/82	-3180	-3406	161	151
1982/83	-2481	-2645	148	117
1983/84	-2747	-2852	147	115
1984/85	-2916	-3273	205	140
Mean	-2959	-3182	166	136

The strength of the linear association between cumulative minimum daily temperature and chillometer varied among the weather severity stations (Table 10). The linear association between chillometer and cumulative minimum daily temperature was very poor and not significant ($P>0.05$) for Piney, Marchand, and Lundar. Sample size is small for Piney and Marchand; however, there is a great deal of variability in cumulative minimum daily temperature and a much larger correlation coefficient should have resulted if a relationship did exist. Chillometer data from Piney were utilized for Marchand which helps explain the identical, low F values for Marchand and Piney. The linear association approached statistical significance ($P=0.05$) for Gypsumville and Riverton. The linear association for Garland was relatively strong ($r^2=.659$); however, the small sample size appears to have been responsible for the lack of statistical significance at $P=0.05$. The relationship between chillometer and cumulative minimum daily temperature was highly significant ($P<0.005$) for Lac du Bonnet, Hodgson and Bissett.

Table 10. Linear correlations relating chillometer to cumulative minimum daily temperature for each weather severity monitoring station.

WEATHER SEVERITY MONITORING STATION	NUMBER OF YEARS OF DATA	r	r^2	F	P
Garland	5	-.812	.659	5.80	<0.10
Piney	5	-.037	.001	.003	>0.25
Marchand	5	-.037	.001	.003	>0.25
Gypsumville	8	-.676	.457	5.04	<0.10
Riverton	8	-.676	.457	5.04	<0.10
Lac du Bonnet	8	-.952	.906	57.83	<0.005
Lundar	8	-.466	.217	1.66	>0.25
Hodgson	8	-.961	.925	74.00	<0.001
Bissett	8	-.926	.851	34.27	<0.005

The number of weeks of available data varied between years for individual stations and between stations for most years (Table 11). The greatest difference was apparent for Lundar where 25 measures were available for 1978/79 and 1981/82 and only 20 measures available for 1984/85. A proportion of the chillometer data represents estimates rather than actual measures.

Table 11. Number of weeks of available chillometer data for the winters 1977/78 to 1984/85.

WEATHER SEVERITY MONITORING STATION	YEAR							
	1977/78	1978/79	1979/80	1980/81	1981/82	1982/83	1983/84	1984/85
Gypsumville	24	25	22	23	23	24	22	22
Riverton	23	25	23	23	25	24	22	23
Lac du Bonnet	23	25	24	23	24	22	22	22
Lundar	24	25	22	23	25	22	22	20
Hodgson	23	25	23	23	22	24	22	23
Bissett	23	25	23	23	23	22	22	22

Snow Depth

Appendix II details cumulative snow depth values for each weather severity monitoring station. Estimates comprise a portion of the data utilized to construct snow depth values. These estimates occur when interpolation can be made between collected measures of snow depth. Estimates also occur at the beginning and end of winter when snow depths are generally low. The effect of these two sources of estimation on cumulative snow depth is not too significant when the magnitude of annual environmental variability is considered.

Pentrometer

Pentrometer values are detailed in Appendix II for each weather severity monitoring station. Table 12 details a series of crust, snow depth, and pentrometer measurements from one winter of data collection. This series is atypical in that it represents a year of extreme snowfall; however, it is typical in terms of the relationship between pentrometer and snow depth measurements.

Table 12. Crust, snow depth, and pentrometer measurements from Ashern for the winter of 1978/79.

DATE		CRUST[a]	SNOW DEPTH (cm)	PENTROMETER (cm)
13	November	1	7	7
20		1	10	10
27		1	21	21
4	December	1	23	22
11		1	24	24
18		1	22	22
25		1	24	23
1	January	1	35	33
8		1	38	36
15		1	41	34
22		1	33	31
29		1	40	40
5	February	1	40	40
12		1	46	45
19		2	51	49
26		2	48	47
5	March	2	47	45
12		2	65	62
19		3	50	0
26		3	59	9
2	April	3	62	9
9		3	66	18
16		3	43	3
23		1	0	0
30		1	0	0

[a]Crust is a subjective measure of the strength of the crust. The following crust conditions are represented by the numbers in the table:

1 - No crust.
2 - Light crust.
3 - Crust strong enough to support a man on snowshoes.

Snow depth and pentrometer measurements were essentially the same for the majority of the 1978/79 winter at Ashern (Table 12). Pentrometer measurements were often similar to snow depth measurements when the snow was quite deep. This indicates that the pentrometer was sinking to ground level under these conditions. It was only when significant crusting occurred that pentrometer measurements became substantially less than snow depth measurements.

There was a highly significant linear relationship between cumulative snow depth and cumulative pentrometer for all weather severity monitoring stations with the exception of Piney (Table 13). The relatively low significance level for Piney likely results from a small sample size rather than lack of a relationship.

Table 13. Linear correlations relating cumulative snow depth and cumulative pentrometer for each weather severity monitoring station.

WEATHER SEVERITY MONITORING STATION	NUMBER OF YEARS OF DATA	r	r^2	F	P
Garland	5	.981	.962	75.90	<0.005
Piney	5	.839	.704	7.14	<0.10
Marchand	5	.996	.992	372.00	<0.001
Gypsumville	8	.819	.671	12.24	<0.025
Riverton	8	.959	.920	69.00	<0.001
Lac du Bonnet	8	.986	.972	208.29	<0.001
Lundar	8	.980	.960	144.00	<0.001
Hodgson	8	.968	.937	89.24	<0.001
Bissett	8	.985	.970	194.00	<0.001

A strong linear relationship between snow depth and pentrometer is to be expected. Pentrometer values are highly dependent and essentially the same as snow depth values until crust formation impedes movement of the pentrometer, therefore cumulative pentrometer values will generally be high

when cumulative snow depth is high and low when cumulative snow depth is low.

The r^2 values for Lundar, Hodgson and Bissett were very high despite the estimate that few measurements were actually collected (an average of 0%, 6.4% and 19% respectively). It is likely that pentrometer measures are collected infrequently because pentrometer and snow depth are similar. Substitution or estimation of pentrometer values likely contributed to the strength of these linear relationships. At the same time, strong linear relationships were apparent for Marchand and Garland where the great majority of pentrometer data were collected (an average of 93.4% and 93.8% respectively). The two weather severity monitoring stations with the lowest r^2 values were Piney and Gypsumville. Each data base for these stations represented an intermediate condition where approximately one-half of the data were estimated.

Temperature and Snow Depth

There was a significant relationship ($P<0.05$) between cumulative snow depth and cumulative minimum daily temperature for 5 of the weather severity monitoring stations (Table 14). Probability levels for 3 stations (Piney, Gypsumville, Bissett) were low given the sample sizes but not significant at 0.05. These P values are low enough to indicate a strong likelihood of statistically significant relationships at larger sample sizes. The closest meteorological station was often located some distance from the weather severity monitoring stations. Ambient temperatures at these meteorological stations might be less than perfectly representative of temperatures at weather severity monitoring stations. An inverse relationship (negative r value) was apparent for all the stations examined. The negative correlation coefficient indicates that snow accumulation is generally greater during colder winters.

Table 14. Linear correlations relating cumulative snow depth to cumulative minimum daily temperature for each weather severity monitoring station.

WEATHER SEVERITY MONITORING STATION	NUMBER OF YEARS OF DATA	r	r^2	F	P
Garland	5	-.420	.176	0.64	<0.25
Piney	5	-.790	.624	4.98	<0.25
Marchand	5	-.917	.841	15.87	<0.05
Gypsumville	8	-.598	.358	3.35	<0.25
Riverton	8	-.774	.599	8.96	<0.025
Lac du Bonnet	8	-.767	.588	8.56	<0.05
Lundar	8	-.769	.591	8.67	<0.05
Hodgson	8	-.736	.542	7.10	<0.05
Bissett	8	-.623	.388	3.80	<0.10

Garland was the only weather severity monitoring station for which there was a very weak association between temperature and snow depth. The sample size was small for this station; however, variability was apparent for both parameters. One difference between Garland and the other stations is that Garland is likely influenced in its weather by the adjacent Duck Mountains while the other stations are located on relatively flat terrain. Temperature data for Garland were provided from the Dauphin Airport meteorological station. Significant differences in temperature regime may exist between Garland and Dauphin due to the presence of the Duck Mountains. Winds are generally westerly or southwesterly at Dauphin during the winter while winds at Garland are probably northerly (R. Clyde, Can. Atmospheric Environment Service, pers. commun.), hence air masses may not emanate from the same source.

Impact of Metrification on the Verme Weather Severity Index

Snow depth and pentrometer were measured in an Imperial unit (foot) by Verme (1968) and in a metric unit (cm) in Manitoba. Use of the metric unit of measurement substantially impacts the influence of the chillometer

(Table 15). The contribution of the chillometer to the WSI decreased from 55% for the Verme WSI to only 4% when snow depth and pentrometer were converted to metric equivalents.

Table 15. The impact of measuring snow depth and pentrometer in metric units on the relative contribution of the chillometer to the Verme Index.

Theoretical Verme WSI	100[a]
Theoretical contribution of:	
(a) Chillometer	55 kW•hours
(b) Snow component	45 feet
Metric equivalent of theoretical value	55 (chillometer) + 45 x 12 x 2.54 (conversion of snow component to metric) = 1427
Contribution of chillometer to WSI: (a) Verme WSI	55%
(b) Metric equivalent	4%

[a]White-tailed deer may experience difficulty above a WSI of 100 in Michigan (Verme 1968).

The chillometer contributed between 11.5% (Bissett) and 17.1% (Garland), on average, of the WSI value when snow depth and pentrometer were measured in cm (Table 16). The lowest annual contribution was 6.4% (Bissett) while the greatest was 31.6% (Lundar).

Table 16. Relative contribution (%) of chillometer to WSI values (metric) for each weather severity monitoring station.

WEATHER SEVERITY MONITORING STATION	NUMBER OF YEARS OF DATA	%	
		Range	Mean
The Pas	3	10.7-16.8	14.0
Garland	5	8.8-26.6	17.1
Piney	5	9.6-22.0	14.6
Marchand	5	8.8-25.9	17.0
Gypsumville	8	10.9-21.1	13.4
Riverton	8	8.2-19.4	13.6
Lac du Bonnet	8	7.8-22.5	13.3
Lundar	8	7.8-31.6	17.0
Hodgson	8	7.5-21.2	13.0
Bissett	8	6.4-16.0	11.5

Effect of Interrelationship of Constituent Variables on an Index

Table 17. Theoretical example illustrating the influence of non-independence of constituent variables on index formation.

Theoretical Manitoba relationships	Pentrometer = Snow depth x .5 Chillometer = Snow depth x .25
Theoretical cumulative snow depth	Year A - 100 Year B - 200
WSI using theoretical Manitoba relationships	Year A - WSI = 100 (snow depth) + 50 (pentrometer) + 25 (chillometer) = 175 Year B - WSI = 200 (snow depth) + 100 (pentrometer) + 50 (chillometer) = 350

The theoretical example in Table 17 illustrates how linear relationships between constituent variables influences the viability of an index. The snow depth in Year B was twice that of Year A in the theoretical example. The Manitoba Weather Severity Index in Year B was also twice that of Year A. The relative change from Year A to Year B was exactly the same for both snow depth and the Manitoba Weather Severity Index. An attempt to relate any independent variable to the Manitoba Weather Severity Index would produce exactly the same degree of association as would an attempt to relate it to snow depth.

Quality Control

Several weather severity monitoring stations were inspected to determine if standards of data collection were being maintained. In several cases, personnel collecting the data were not aware that standards existed or if they were in possession of such standards.

The accurate measurement of snow is affected to some degree by characteristics of a site. The habitat at 1 site (Hecla South) included a great deal of residual grass which often served to suspend snow above ground level.

One problem related to the measurement of snow depth is specific to the spring. At this time of year, the snow adjacent to the ruler often melts creating a depression in the snow around the ruler. Four of the people collecting data recorded snow depth by estimating the depth at the top of the depression. This was done by putting a ruler or other straight-edge across the depression or by sighting along the surface of the snow. One data collector recorded the snow depth at the bottom of the depression thereby underestimating snow depth by approximately 2 to 5 cm. At 1 monitoring site, 1 of the rulers was not vertical thereby slightly increasing the estimate of snow depth. There were only 9 stations at 1 monitoring site as opposed to the standard of 10 stations. Individual stations were marked at 1 monitoring site; however, rulers were not attached to the markers. The data collector utilized a ruler to subjectively sample the snow depth around the site. If the depth was not

felt to be representative, another location near the station was sampled. One data collector indicated that snow sometimes accumulated along 1 side of the station marker and that he was uncertain how to measure snow depth under these circumstances. This is one example of specific problems which became apparent following discussion with the data collectors. One of the data collectors indicated that he had not planned to collect measurements because most of the snow had disappeared but snow depth measurements were obtained at approximately one-half of the stations when they were sampled. The measurement of cumulative snow depth is probably not affected substantially by the difficulties and inconsistencies apparent in the collection of the data.

The methodology relative to the use of the pentrometer was quite variable. In several cases, the data collector dropped the pentrometer from a distance above the surface of the snow. One data collector broke through a surface crust and then dropped the pentrometer. These divergences from standard methodology would elevate pentrometer values. There was some variability relative to the specific time when sampling was conducted. Pentrometer values could be related to sampling time under conditions of crusted snow. One data collector indicated that he had not planned to utilize the pentrometer and another data collector did not utilize the pentrometer when sampling. It is difficult to assess how significantly the cumulative pentrometer measurement is affected by inconsistent methodology and non-collection of measurements.

DISCUSSION

Chillometer

The Weather Severity Index described by Verme (1968) was developed to measure weather severity as experienced by white-tailed deer in Michigan. Verme (1968) monitored the effect of ambient temperature, wind, solar radiation, snowfall and relative humidity on chillometer measurements. Wind and temperature were the only environmental factors which influenced the chillometer. Wind, although statistically significant, exerted a negligible influence on the chillometer when compared to the strong influence of

ambient temperature. The minimal influence of wind on the chillometer is likely a function of the site where the monitoring was carried out. Verme (1968) indicates that the chillometer was located in "a small clearing completely exposed to prevailing winds". Small clearing is not defined; however, the picture of a monitoring site included in the paper [Fig. 2 in Verme (1968)] illustrates that substantial cover is located very close to the chillometer. Wind velocity and profile is related to the life-form, height and density of vegetation (Moen 1973). The wind velocity which the chillometer was subjected to was probably minimal due to the influence of the surrounding vegetation. A downward vector would be apparent in the wind profile of a small clearing and the effect of wind might have been mitigated somewhat by the roof located above the chillometer. The operationally insignificant effect of wind was likely the result of the protection afforded the chillometer by adjacent and wooded cover. This is probably a biologically correct measurement for the Michigan hardwoods forest which would very substantially ameliorate the effects of wind on white-tailed deer.

Solar radiation, snowfall and relative humidity did not exert a measurable effect on the chillometer. Verme (1968) felt that the influence of solar radiation and snowfall was substantially decreased due to the presence of the roof above the chillometer. Operative temperature is a measure which incorporates ambient temperature, wind and thermal radiation. Mammals utilize additional energy to maintain body temperature when the operative temperature of the environment is outside their thermal neutral zone. The thermal neutral zone is bounded by a lower critical temperature as its lower end and by an upper critical temperature at its upper end (Bartholomew 1972). Energetic inputs will be required at temperatures below the lower critical temperature. Solar radiation can influence operative temperature such that it is significantly higher than ambient temperature. Ungulates may be subjected to ambient temperatures well below their lower critical temperature yet the operative temperature of the environment may be well above their lower critical temperature due to solar radiation (Parker and Robbins 1985). Solar radiation is a potentially important environmental

variable which is not monitored by the chillometer. The value of the chillometer as a measure of thermal stress is subject to question because solar radiation is not measured.

Chillometer data collected at weather severity monitoring stations in Manitoba are of little value. Verme (1968) found a strong linear relationship between temperature and chillometer with the chillometer measurement increasing as temperature decreased. A strong linear relationship between temperature and chillometer should have been found for data from Manitoba. A number of examples from specific stations are indicative of the poor or non-existent relationship. Chillometer values were often the reverse of what was expected when relatively cold winters were compared to relatively warm winters at weather severity monitoring stations.

There are a number of potential explanations for these unexpected results. Chillometers are difficult to calibrate and the setting can be disturbed when the chillometer is transported to the monitoring site. The extent of the missing data and the practice of estimating data when values were missing may have significantly affected results. The number of weeks of data collection varied somewhat between years thereby influencing chillometer values. Minimum daily temperature was accumulated for the period 01 November to 30 April inclusive. Selection of a slightly different period of measurement would have yielded somewhat different results. The temperature data used in the analysis came from meteorological stations located varying distances from the weather severity monitoring stations. Temperature may not have been directly representative of weather severity monitoring stations; however, relative changes between years would likely be similar (D. Soprovich, Man. Wildlife Branch, unpubl. data).

The specific microclimate located at chillometer sites likely influenced results substantially. Site selection was dictated by the availability of a power source for the chillometer. This pragmatic concern resulted in the selection of sites exhibiting considerable variability relative to exposure to wind. No standards existed to control the degree to which chillometers were exposed to wind. Variation in the amount and timing of wind between years likely had a significant effect upon results.

Comparison of data from Lundar to that from Hodgson illustrates the probable effect of site selection on the data. Winters at Hodgson were colder than those at Lundar yet chillometer values at Lundar were higher than those at Hodgson for 7 of the 8 years examined, a reversal of what is expected. The chillometer at Lundar had very little protection from the wind. A large field approximately 1.5 km in length was located northwest of the chillometer with little protection being afforded in other directions. The chillometer at Hodgson was well protected to the north, northwest, northeast, and east and was substantially more protected from potential wind effects than was the chillometer at Lundar. The net effect of the lack of standardization relative to exposure is that values are representative of specific sites where chillometers were located rather than local conditions.

Wind was not a significant factor affecting the chillometer in the model presented by Verme (1968) but probably is a significant factor affecting the chillometer at some of the monitoring sites in Manitoba. Wind can substantially decrease the insulative capabilities of hair leading to increased energy requirements (Parker and Robbins 1985). Ungulates can utilize cover to minimize the effects of wind (Moen 1968) and appear to select sites and posture for thermal benefit (Gates and Hudson 1981; Parker and Robbins 1985). The energy balance of white-tailed deer is related to the quality of the food available to them. If the quality of the food is high, deer can maintain a positive energy balance when exposed to operative temperatures outside their thermal neutral zone (Moen 1968). The quality of food resources being utilized is probably high when white-tailed deer and elk are found foraging in open environments in Manitoba. A measure of thermal stress should not include wind effects if such effects are minimized through the use of wooded cover and energetic output is not increased. Ungulate populations found in Manitoba generally utilize wooded cover during the winter period. Those chillometers which are influenced significantly by wind are likely poor measures of thermal stress as experienced by such populations. This does not preclude the possibility that some populations of ungulates in Manitoba are subjected to relatively significant thermal

stress as a result of exposure to wind (e.g., moose utilizing the marsh and willow habitat of G.H.A. 8 could potentially be influenced by wind).

It was expected that a strong linear relationship between chillometer and temperature would be found for each weather severity monitoring station. The lack of a relationship or the presence of a relatively poor relationship was found for 6 of the stations. The 3 stations for which no relationship was found were also the stations with the greatest amount of data estimated to be missing. Strong relationships were found for only 3 of the 9 weather severity monitoring stations. There was a great deal of variability among stations relative to the strength of the relationship between chillometer and temperature. The variability indicates that factors other than temperature were affecting each station to a different degree and that stations are not directly comparable to each other. Chillometer data cannot be used to assess relative severities between localities because data are not representative of localities but specific sites. The primary purpose of the chillometer is to provide information to allow the comparison of years and localities. It appears that the chillometer has not provided a biologically valid or useful measure of thermal stress as experienced by Manitoba ungulates.

Snow Depth

Snow depth measurements were estimated when data were not collected or were missing for some other reason. Estimates were generated by interpolation whenever this method was possible. This results in some amount of error; however, it is important to recognize that the methodology of using weekly measurements is, in itself, a form of interpolation and therefore subject to inaccuracy. Error will result because exact measurements of snow depth are not available and snow depth directly influences the energetic requirements of locomotion by ungulates (Fancy and White 1985). Snow depth is one characteristic of snow which can restrict the movement and habitat selection of caribou, (Rangifer tarandus) (Pruitt 1978). Snow depth also directly influences the quality and quantity of food resources available to many ungulates. The amount of food available to

white-tailed deer is dependent upon snow depth and will vary with habitat (Moen and Evans 1971) while foraging tactics of elk are directly influenced by snow depth (Gates and Hudson 1981). Available winter range and food resources of mule deer (Odocoileus hemionus) are influenced by snow depth (Wallmo and Gill 1971). The literature is replete with examples of how ungulates are affected by snow depth.

There are data which are missing from the beginning and end of the winter. Snow depths at these times are generally low enough that the energetic cost of locomotion is minimal (see Fancy and White 1985). This source of error may be significant in that the availability of food resources may be influenced at such depths. This may be of particular importance to young animals which are actively growing and accumulating fat reserves. The impact of early snow which excludes high quality food could be significant to survival of this age class. The missing data may be an important source of error when attempting to determine impact of temporal snow conditions (eg., effect of early snow). The missing data have a minor impact upon cumulative snow depth over the complete winter.

Pentrometer

The pentrometer or compaction gauge is one component of the Weather Severity Index developed by Verme. The pentrometer is a tube approximately 61 cm (2 feet) in length and approximately 1.36 kg (3 pounds) in weight. This instrument exerts a pressure of approximately 211 g/cm^2 (approximately 3 pounds/inch^2) on the surface of the snow. The intent of this instrument is to measure the degree to which white-tailed deer are supported by snow. The inference is that snow depth does not impact the ability to move as severely when some level of support is available and that support offered by the snow could make additional food resources available to white-tailed deer. With the exception of conditions of weak surface crust, the compaction gauge closely simulated sinking depths of white-tailed deer in snow conditions found in the Michigan hardwoods forest (Verme 1968).

The pentrometer is not supported by the snow depths and densities

found in wooded cover in Manitoba. The pentrometer sinks to ground level until a surface crust develops, generally during the later part of the winter. The lack of support of the pentrometer prior to crust formation is likely a result of the considerably different snow conditions found in Manitoba. Snowfall in parts of southern Manitoba average approximately 114-140 cm/year (45-55 inches/year) while snowfall over much of the Upper Michigan Peninsula amounts to more than 254 cm/year (100 inches/year) (Ransom 1964). There is a great deal more snow in this area of Michigan which is available to be compacted and to support deer. Heat is one factor which influences the structure of a snow cover (Pruitt 1978). Ambient temperature is considerably higher in the Upper Peninsula as compared to Manitoba (Ransom 1964) and periodic thaws during midwinter result in lowered snow depths and strong crusts (Verme and Ozoga 1971). This difference in temperature likely contributes to the different performance of the pentrometer in Manitoba.

The pentrometer does not sink to ground level when surface crusts of adequate density develop. The surface crust may completely support the pentrometer or may impede it partially. Verme (1968) indicated that a weak surface crust presented problems with the accuracy of pentrometer measurements. At times, the pentrometer would be supported on the surface of the snow when it was observed that deer were breaking through the crust. This inadequacy was controlled somewhat by conducting measurements at midday when solar radiation had weakened the crust.

White-tailed deer breaking through surface crusts capable of supporting a pentrometer have been observed in Manitoba (D. Chranowski, Man. Wildlife Branch, pers. commun.). The methodology for taking pentrometer measurements in Manitoba is such that measurements are collected in the morning. It is probable that a significant portion of the pentrometer measurements taken under conditions of surface crust in Manitoba indicate that white-tailed deer are being supported by the crust when deer are breaking through the crust. The pentrometer exerts a pressure of approximately 211 g/cm^2. Table 18 provides estimates of foot load or surface pressure for various sex and age classes of white tailed deer. Telfer and Kelsall (1979) estimated these foot loads for white-tailed deer

collected from Elk Island National Park in Alberta. Kucera (1976) estimated foot load (17 observations) at 200-400 g/cm^2 and 500 g/cm^2 for walking and running yearling and adult white-tailed deer from the Delta Marsh. The observations were likely collected during February and/or March (E. Kucera, Man. Hazardous Waste Corporation, pers. commun.) when body weight would have been substantially less than the deer examined by Telfer and Kelsall (1979). These foot loads are substantially greater than 211 g/cm^2 which indicates that the pressure exerted on the surface of the snow by deer would be substantially greater than that exerted by the pentrometer.

Table 18. Foot loads (g/cm^2) of white-tailed deer for various sex and age classes. Data from Telfer and Kelsall (1979).

SEX	AGE	NUMBER IN SAMPLE	RANGE	MEAN
Male	.5	6	239.7 - 360.8	287.8
	1.5	10	358.0 - 511.8	412.5
	2.5	5	490.7 - 575.8	536.1
	3.5	7	466.5 - 591.0	519.5
	4.5	11	439.9 - 602.1	512.0
Female	.5	14	255.6 - 374.8[a]	327.5
	1.5	13	263.1 - 500.3	427.7
	2.5	11	374.9 - 567.8	467.1
	3.5	6	396.3 - 556.0	474.3
	4.5	10	374.1 - 564.7	474.3

[a]Upper range was 274.8 in Telfer and Kelsall (1979) but should have been 374.8 (E. Telfer, Can. Wildlife Service, pers. commun.).

There is a great deal of difference between the various age and sex classes relative to foot load. Fawns have substantially lower foot loads than do older deer which could be an advantage under conditions of dense snow or hard crust (Telfer and Kelsall 1979). Foot loads of deer older than fawns are substantially greater than the surface pressure exerted by the pentrometer. It is expected that the pentrometer would be a poor indicator of support for these older deer under the conditions of surface crust experienced in Manitoba. This knowledge explains observations

of deer breaking through surface crust in Manitoba. The pentrometer could be useful for the estimation of annual mortality if it simulated the support available to fawns because it is this age class which represents the majority of the deer which die over the winter. The pentrometer would probably be relatively poor for the estimation of the impact of snow on adult does and subsequent mortality of fawns born in the spring because foot loads of adult does are substantially greater than the pentrometer.

The estimates of foot load were made on the basis of pressure exerted on a surface when all four feet were on the surface (Telfer and Kelsall 1979). The definition of foot area or supportive area used to calculate foot load appears to be somewhat liberal. The apparent inflated estimation of supportive area, the fact that white-tailed deer do not have all four feet on the ground when moving and the additional force resulting from the foot descending into contact with the surface of the snow combine to indicate a substantially higher surface pressure being generated than the foot load estimates of Table 18. The factors which indicate a much higher realistic surface pressure are offset somewhat by the fact that foot loads are directly related to body weight. The measures used to estimate the foot loads in Table 18 were made from white-tailed deer collected between 01 December and 17 December (Telfer and Kelsall 1979). Fawn body weights would likely have been near their maximum during that period. Fawn body weights can vary substantially during the winter and may be considerably lower by the time crust conditions are encountered in Manitoba. Foot area may increase marginally over the winter. These two factors, but particularly weight loss, would lead to substantially lower foot loads being calculated for fawns during the later part of some winters. The pressures exerted on the surface of the snow by a white-tailed deer fawn in late winter may approach the pressure generated by the pentrometer but would likely be significantly greater when all factors are considered. Field testing of the pentrometer would be required to determine exactly how accurate or inaccurate it is as a measure of support to fawns by crust conditions found in Manitoba. The relatively late period of data collection and subsequent low body weights likely had a very substantial influence on the foot load values reported by Kucera (1976). Additionally, Kucera (1976)

estimated foot load by pushing a hardness guage to the sinking depth of the deer as opposed to estimating the crust hardness necessary to support a deer.

The problem of deer breaking through a surface crust when the pentrometer indicates that they are being supported is critical for two reasons. Locomotion is more energetically demanding when ungulates are breaking through a crust as compared to movement through uncrusted snow of the same depth (Fancy and White 1985). The pentrometer may indicate total support and contribute nothing to the severity index when substantial additional inputs of energy are required due to a weak surface crust. At the same snow depth and under conditions of no crust, the pentrometer would sink to ground level thereby contributing significantly to the severity index and erroneously indicating a more stressful snow cover. The second reason relates to foot loads of predators like coyotes (Canis latrans) and wolves (Canis lupus). Coyote and wolf foot loads were calculated on the basis of data found in Telfer and Kelsall (1984). The mean foot load for 3 adult male coyotes was estimated at 140 g/cm^2. The mean foot load for 5 adult wolves was estimated at 150 g/cm^2. These foot loads are substantially less than those of white-tailed deer. It is probable that under certain conditions, white-tailed deer are breaking through a crust which supports both a pentrometer and either of the above predators. The pentrometer would indicate support of the deer under these conditions and would not contribute to the weather severity index; yet, the prey species would be significantly more vulnerable to predation.

Additional problems are apparent relative to the use of the pentrometer. The pentrometer was developed for use in the hardwoods forest of Michigan where deer utilize the forbs, grasses and browse available throughout the winter. White-tailed deer and elk found in Manitoba often have access to agricultural products and residues which may be found in close proximity to wooded cover. White-tailed deer will often utilize a trail network to make use of these food resources (D. Chranowski, Man. Wildlife Branch, pers. commun.) and are not required to forage as extensively throughout wooded cover. The consequence of this behaviour is that such deer are not subject to the same energetic demands of locomotion

as are deer which utilize wooded cover alone. White-tailed deer in the agricultural areas of Manitoba may be forced to forage in wooded cover when snow depth excludes the availability of agricultural residues. A final problem with use of the pentrometer is that the negative impacts of crust formation on food availability are not considered in the measurement. While crusts may allow ungulates to move about more easily, they also may function to exclude food of potentially high quality. This factor may be of more importance, at times, than the ability to move about freely and consume food of poor quality.

The pentrometer was developed as an indicator of support for white-tailed deer. This measure should not be included in the construction of a weather severity index for other species of ungulates in Manitoba. Foot loads of elk and moose are considerably greater than white-tailed deer of comparable age and sex while foot loads of caribou might be similar to the pentrometer. Telfer and Kelsall (1979) provide estimates of foot loads for elk and moose. The mean foot load by age and sex group varied between 457.7 and 737.6 g/cm^2 for elk and between 389.5 and 658.8 g/cm^2 for moose. The range for male elk calves was from 329.3 to 630.5 g/cm^2 while the range for male moose calves was from 313.5 to 440.8 g/cm^2. These foot loads are much greater than the pressure exerted by the pentrometer hence the pentrometer would be a very poor simulator of support for these species. The only potential use of the pentrometer under these circumstances would be in formulating an indicator of predation pressure. The pentrometer would be roughly indicative of crust conditions supportive of wolves. The combination of snow depth and the potential for the prey species breaking through under crust conditions might yield some measure of vulnerability to predators. Field data would be necessary to determine the potential value of the pentrometer in this regard.

Caribou foot loads were calculated on the basis of data found in Telfer and Kelsall (1984). The mean foot load of adult caribou was estimated at 190 g/cm^2 which compares favourably with the pentrometer. Pruitt (1978) indicated that thickness, hardness and density gradients influence the distribution of wintering caribou. Pruitt (1979) believed

that surface hardness is probably the most important aspect of a snow cover for caribou because caribou test this characteristic. Empirical evidence is presented by Pruitt (1981) to show that the Värriö Snow Index (based upon hardness and thickness) successfully indicates differences in snow cover between areas used by wintering caribou, areas used occasionally by wintering caribou and areas not used by wintering caribou. A difficulty with this empirical information is that the significant difference in snow cover (Värriö Snow Index) could be the result of only one of these variables.

A major purpose for the collection of the environmental data was to allow comparison of weather severity between geographic areas. It is not possible to use pentrometer information to compare crust conditions between stations because the extent of missing data is different for each station.

Strong linear relationships between cumulative snow depth and cumulative pentrometer were apparent for the majority of the monitoring stations. A strong linear relationship was apparent for both Garland and Marchand where it was estimated that actual measures were responsible for the great majority of the data. These relationships are important relative to their impact on an index. An index constructed by the addition of pentrometer and snow depth measurements will be almost identical numerically to multiplication of the snow measurement by a constant when there is a strong linear relationship between measures. The consequence is that such an index behaves in almost an identical manner as does cumulative snow depth. An attempt to relate an independent variable to such an index would produce results similar to an attempt to relate the independent variable to cumulative snow depth. The construction of an index under these circumstances does not refine the severity measure significantly, provides little additional information and provides no advantage over the use of cumulative snow depth alone. Analysis of snow conditions on a temporal basis could potentially be improved with the use of support information.

A number of difficulties have been identified relative to the use of the pentrometer as a measure of winter severity for white-tailed deer. Some of these difficulties are pertinent to each of the other species of

ungulate found in Manitoba. The concept of measurement of support is a valid concept. The use of the pentrometer under Manitoba snow conditions for a variety of species does not accomplish this task.

Temperature and Snow Depth

It would appear that snow depth was inversely related to temperature at 8 of the 9 weather severity monitoring stations. Cold winters were associated with greater cumulative snow depths. Garland was the only station for which there was definitely no relationship. The lack of relationship may have been due to differences in weather patterns between Garland, where snow depths were measured, and Dauphin, where temperature was measured.

The inverse linear relationship between snow depth and temperature is important relative to its impact on an index. The problem is identical to that discussed for the snow depth and pentrometer relationship. The addition of a measure of temperature to cumulative snow depth provides only partial information because the measurement of cumulative snow depth effectively measures temperature. The relationship between snow depth and temperature does not exhibit the strength of the relationship between snow depth and pentrometer. This results in relatively greater information being provided by the measurement of temperature.

Impact of Metrification on the Verme Weather Severity Index

The Verme Weather Severity Index was constructed with the use of an Imperial unit of measurement (foot) for both snow depth and pentrometer. Snow depth and pentrometer have been measured in cm in Manitoba. Manitoba has kW·hours as units of measurement for the chillometer, the same unit used by Verme (1968).

The Verme Weather Severity Index is essentially a model with the hypothesis that the addition of snow depth and pentrometer measurements (in Imperial units) to chillometer measurements results in a number which is indicative of environmental stress to white-tailed deer. The contribution of the chillometer component to total WSI was greater than the combined

contribution of the other components in northern Michigan (Verme 1968). Verme (1968) believed that thermal stress was more important than curtailed mobility to white-tailed deer and that the greater relative contribution of the chillometer was appropriate. The above information leads to a logical corollary to the hypothesis. This corollary is that thermal stress is most critical to white-tailed deer and should be reflected appropriately within WSI.

If the weather severity index is not measured exactly as defined, it is no longer a Verme Weather Severity Index but represents some other model. Examination of a theoretical Verme WSI of 100 illustrated that measurement of snow depth and pentrometer in metric units would substantially decrease the importance of the chillometer to the WSI. Verme's model suggests that the chillometer should represent an even greater proportion of the Verme WSI in Manitoba where winters are substantially colder and snowfall less as compared to Michigan. The opposite was true due to the measurement of snow depth and pentrometer in metric units. It is obvious that the use of metric measurements in Manitoba has distorted the hypothesis and corollary of Verme's model to the extent that it is no longer a Verme Weather Severity Index.

The index of weather severity to white-tailed deer as generated in Manitoba does not constitute a Verme Weather Severity Index because the hypothesis and corollary are violated by the method of data collection utilized in Manitoba. The consequence of this violation is that biological relationships between the Verme Weather Severity Index and white-tailed deer which have been found in other geographic areas are irrelevant to the measure of weather severity in Manitoba. The numbers generated by the Manitoba Weather Severity Index are meaningless until they have been supported by biological relationships.

Index Formation and the Effect of Interrelationship of Constituent Variables

The three variables which comprise the Manitoba Weather Severity Index are snow depth, pentrometer, and chillometer. It is apparent that the formation of an additive index serves no purpose when pentrometer and

chillometer measurements are perfectly and linearly related to snow depth (see theoretical example in Results). There is a strong linear relationship between pentrometer and snow depth in Manitoba. It was not feasible to evaluate the relationship between the cumulative chillometer measurement and snow depth in Manitoba because of the problems identified with the chillometer data; however, there was a linear relationship between temperature and snow depth in Manitoba. As temperature and chillometer are strongly related in the Verme model, it is to be expected that the chillometer measurement, if collected under standard conditions, would also relate to snow depth in Manitoba. An important consequence of this lack of independence among the components of the WSI is that WSI formation will likely result in little or no improvement over snow depth in predicting the impact of winter weather on ungulates.

The Verme Weather Severity Index and the Manitoba Weather Severity Index result from the addition of several variables. An index represents an attempt to formulate sometimes complex relationships into one value which is simple to understand when comparisons are made. A serious drawback to this procedure is that underlying relationships are masked and may be distorted. Information is lost through the process of index formation.

The formation of an index is understandable given the limited analytical tools available in 1964 when Verme first used this Weather Severity Index (Verme 1968). There is no need to form an index given the analytical tools available today. Green (1979) stated:

> "It is better to use individual criterion or predicator variables in linear additive models and then let the relative magnitudes and signs of the coefficients in the linear additive functions be the basis for interpretation of criterion or predictor variable relationships."

Indices can still be formulated within the framework of modern statistical techniques; however, such indices should be tested to determine whether they provide information additional to the constituent variables. The availability of interaction terms in modern techniques also serves to enhance the analysis of underlying relationships. The relationship between

cumulative snow depth and cumulative pentrometer can create problems of analysis when modern statistical techniques are utilized (similar to the problems created in index formation).

Quality Control

It is apparent that standards of data collection are not being met relative to weather severity information. Chillometer measurements have not been collected for a standardized time period. It is not possible to compare chillometer data from the various weather severity monitoring stations due to the non-standardization of site characteristics. The method of measuring snow depth varies between data collectors. The pentrometer is often not utilized and variation exists relative to how this instrument is utilized. The timing of sampling is variable, a potentially significant factor relative to pentrometer measures. Standards are available which discuss methods of data collection; however, personnel collecting the data are sometimes unaware of the existence of these standards.

The measurement of snow depth is probably not seriously affected by the lack of standardization or the amount of missing data. Pentrometer and chillometer measurements are seriously affected by the lack of standardization and/or the extent of missing data. This problem is important because relationships between biological parameters and environmental measures have not been developed for Manitoba. The problems related to standardization of data collection and the procedure of estimating data when it has not been collected represent poor methodology when the intent of the data collection is to generate relationships. The consequence of this poor methodology is that relationships may be distorted significantly. The substitution of estimates might be an acceptable procedure when relationships have been generated and management information is required but is not acceptable when the intent is to generate relationships.

RECOMMENDATIONS

1. Cease using a chillometer except as a test instrument for environments where ungulates are subject to significant wind effects. Temperature data from meteorological stations can be used as one measure of thermal stress.
2. Cease using a pentrometer. Develop methods which effectively measure the biological impact of crust and snow density based on the biology and morphology of each species of ungulate and field test under Manitoba environmental conditions prior to broad application.
3. Collect snow depth data with the guidance of an experimental design aimed at determining biological relationships found in Manitoba (e.g., the relationship between annual recruitment and snow depth).
4. Improve communication between staff collecting the data and staff who require the data to ensure that data is as accurate as possible. Report back to staff who collected data to ensure that they are aware of both the present use and long-term potential of the data. Send annual reports related to data directly to staff who collect the data.
5. Visit each person who collects the data at least once each winter to discuss methodology and to ensure high standards of data quality.
6. Visit new staff to ensure high standards of data quality are maintained following staff transfers.
7. Do not formulate indices except when they will be tested for improvement of biological relationships.
8. Collect new environmental measures only if an experimental design is present for the development of biological relationships.
9. Avoid the procedure of using measurements from the closest station when data are missing, particularly under conditions of relationship development.
10. Consider the potential impact of site selection prior to the implementation of future environmental data collection programs.
11. Consider the biology specific to each species of ungulate prior to the implementation of future environmental data collection programs.

12. Test some environmental measures under Manitoba conditions with tame or game farm ungulate species (e.g., pentrometer development).
13. Investigate the effect of snow cover on behaviour and energetics to develop measures which reflect the impact of winter weather on ungulates in Manitoba. Investigate the energetic cost of thermoregulation under Manitoba environmental conditions for several species of ungulates.
14. Investigate the relationship between snowfall and temperature with the relatively long time series available in the meteorological records.

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W.S.I. REPORT

Region _____ District _____ Date _____

CHILLOMETER _____ kwh's

PENTROMETER _____ _____ _____ _____ _____ _____ _____ _____ _____ _____

Av. Pentrometer _____

SNOW DEPTH _____ _____ _____ _____ _____ _____ _____ _____ _____ _____

Av. Snow Depth _____

TEMPERATURE _____ _____ _____ _____ _____ _____ _____ _____ _____ _____

Av. _____ Minimum _____ Maximum _____

DEER MOVEMENTS ARE (See code on reverse) _____ ,

by snow pack

CRUST (See code on reverse)

_____

MAJOR WEATHER DURING WEEK (See code on reverse) _____

_____

COMMENTS: _____

_____

_____

_____

_____

OBSERVER

MG-6890

Appendix II. Environmental Data for Weather Severity Monitoring Stations Utilizing a Chillometer.

WEATHER SEVERITY MONITORING STATION	YEAR	CUMULATIVE MINIMUM TEMPERATURE (C)	CUMULATIVE CHILLOMETER VALUE (kw•Hours)	CUMULATIVE SNOW DEPTH (cm)	CUMULATIVE PENTROMETER VALUE (cm)
The Pas	1982/83	-3053	170	838	576
	1983/84	-2566	180	478	412
	1984/85	-3233	216	754	531
Garland	1980/81	-2070	105	203	126
	1981/82	-2816	128	186	167
	1982/83	-2564	139	716	470
	1983/84	-2198	121	354	310
	1984/85	-2749	144	848	647
Piney	1980/81	-2195	125	241	203
	1981/82	-2857	131	486	375
	1982/83	-1996	122	323	278
	1983/84	-2394	78	460	278
	1984/85	-2543	104	447	374
Marchand	1980/81	-2157	125	187	170
	1981/82	-2646	148	484	443
	1982/83	-1937	122	197	158
	1983/84	-2369	78	422	388
	1984/85	-2629	104	430	416
Gypsumville	1977/78	-3310	236	808	763
	1978/79	-3766	181	894	570
	1979/80	-2926	182	651	617
	1980/81	-2313	135	463	356
	1981/82	-3047	175	338	317
	1982/83	-2517	151	679	526
	1983/84	-2650	163	594	513
	1984/85	-3002	162	778	551

... continued

Appendix II (continued)

WEATHER SEVERITY MONITORING STATION	YEAR	CUMULATIVE MINIMUM TEMPERATURE (C)	CUMULATIVE CHILLOMETER VALUE (kW•hours)	CUMULATIVE SNOW DEPTH (cm)	CUMULATIVE PENTROMETER VALUE (cm)
Riverton	1977/78	-3239	172	1012	908
	1978/79	-3626	195	1024	776
	1979/80	-2955	193	977	864
	1980/81	-2448	158	371	306
	1981/82	-3012	151	346	280
	1982/83	-2497	138	334	290
	1983/84	-2794	146	464	446
	1984/85	-2922	142	733	456
Lac du Bonnet	1977/78	-2911	160	913	875
	1978/79	-3300	181	853	747
	1979/80	-2607	158	961	912
	1980/81	-2166	118	350	287
	1981/82	-2718	140	448	359
	1982/83	-2066	119	237	174
	1983/84	-2353	129	477	341
	1984/85	-2579	145	558	373
Bissett	1977/78	-3360	161	766	670
	1978/79	-3614	153	906	751
	1979/80	-2996	135	990	972
	1980/81	-2633	111	356	274
	1981/82	-3204	137	394	327
	1982/83	-2429	111	379	299
	1983/84	-2730	117	570	512
	1984/85	-2971	122	507	355
Hodgson	1977/78	-3403	138	896	796
	1978/79	-3868	171	938	639
	1979/80	-3293	149	908	811
	1980/81	-2717	110	295	235
	1981/82	-3406	151	301	261
	1982/83	-2645	117	292	217
	1983/84	-2852	115	457	400
	1984/85	-3273	140	705	554

... continued

Appendix II (continued)

WEATHER SEVERITY MONITORING STATION	YEAR	CUMULATIVE MINIMUM TEMPERATURE (C)	CUMULATIVE CHILLOMETER VALUE (kW·hours)	CUMULATIVE SNOW DEPTH (cm)	CUMULATIVE PENTROMETER VALUE (cm)
Lundar	1977/78	-3154	192	698	603
	1978/79	-3746	168	1122	852
	1979/80	-2959	181	962	876
	1980/81	-2487	127	318	244
	1981/82	-3180	161	320	277
	1982/83	-2481	148	178	143
	1983/84	-2747	147	416	368
	1984/85	-2916	205	516	337